



#### World Meteorological Organization

Weather . Climate . Water Interprogramme Coordination Team on Space Weather

### Extreme Space Weather Events and **NATO Operations**

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#### Outline of the Talk

- Definition an Extreme Space Weather Event
- Solar-Terrestrial Weather Phenomena
- Extreme SWx Events by Severity
- Semantic Ambiguity in the Definition
- Relevance of ESWxWs for NATO Operations
- SWx Monitoring in the NATO Framework
- Characteristics of SWx Information for NATO Operations

### Definition of an Extreme Space Weather Event

Should be based on:

- 1 A correct semantics
- 2 The energetics of the events' cascade
- 3 The severity of the impacts
- Should be standardised

## Solar-Terrestrial Weather Phenomena

(1) Solar Weather Events

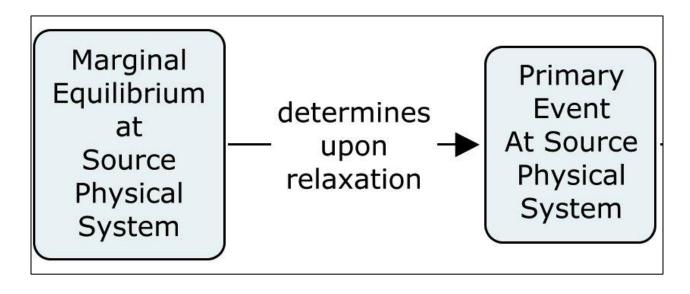
(e.g. Solar Flares)

- 2 Interplanetary Weather Events
- (e.g. CMEs)

3 Geospace Weather Events

- (e.g. CME-MSPH)
- 4 Magnetospheric Weather Events (e.g. GM Storm)
- (5) Ionospheric Weather Events (e.g. TEC variations)
- (6) Geospheric Weather Events (e.g. GICs)

#### Solar Weather Event



Unstable Magnetic Topology in Solar Active Region

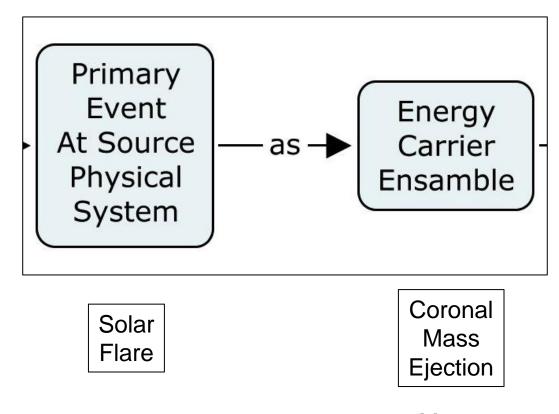
Magnetic Reconnection

Solar Flare

- Sunspot area
- Magnetic topology
- Magnetic helicity
- Parker
- Pile-up
- Stochastic

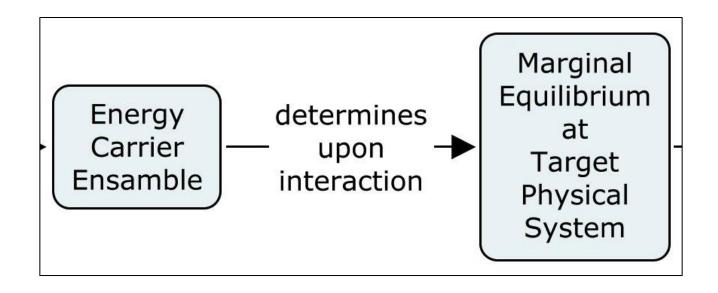
- SXR peak
- SXR lightcurve

### Interplanetary Weather Event



- Mass
- Dynamics
- Geometry

### Geospace Weather Event

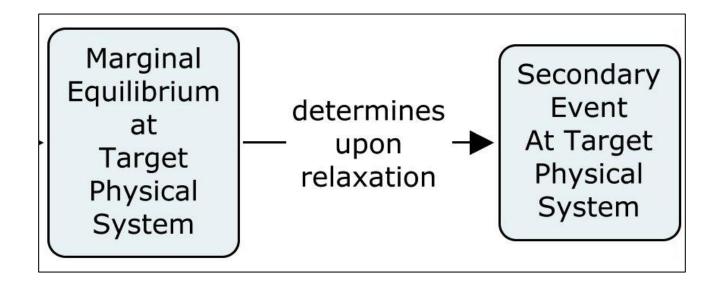


Coronal Mass Ejection

Energy Transfer Unstable
Magnetospheric
Configuration

- Ram Pressure
- Hemispheric Power
- Compression

### Magnetospheric Weather Event



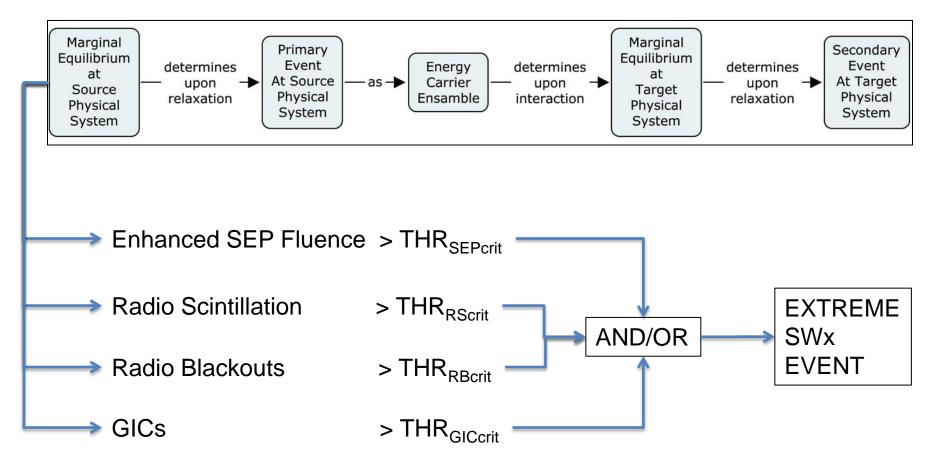
Unstable
Magnetospheric
Configuration

Geomagnetic Storm Geomagnetically Induced Current

- Kp, Dst
- Typology

- Intensity
- Geography

# Extreme Space Weather Event by Impacts' Severity



### Semantic Ambiguity to Be Solved

"Extreme Space Weather event" refers to:

- The Solar Flare
- The Coronal Mass Ejection
- The Geomagnetic Storm
- The Radio Blackout
- The GIC
- The relevant impacts on tech/bio systems
- The whole solar-terrestrial events' cascade

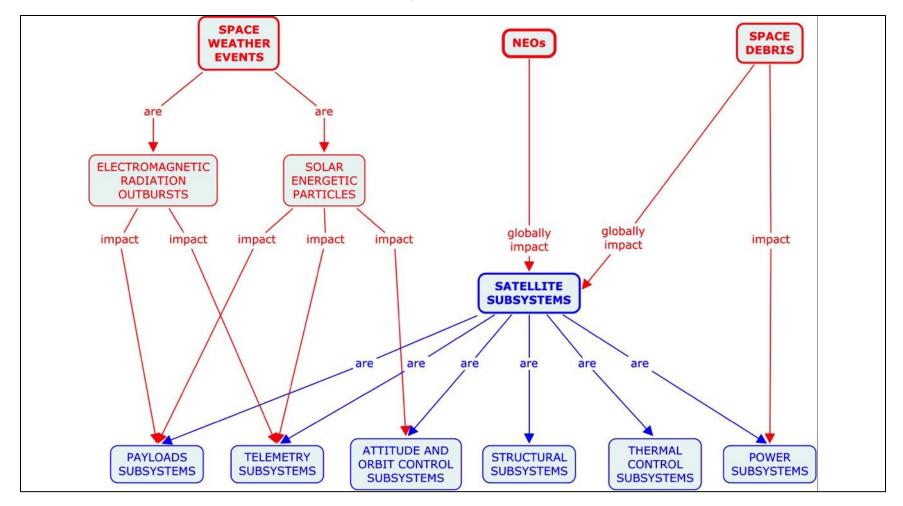


## Relevance of ESWxEs for NATO Operations

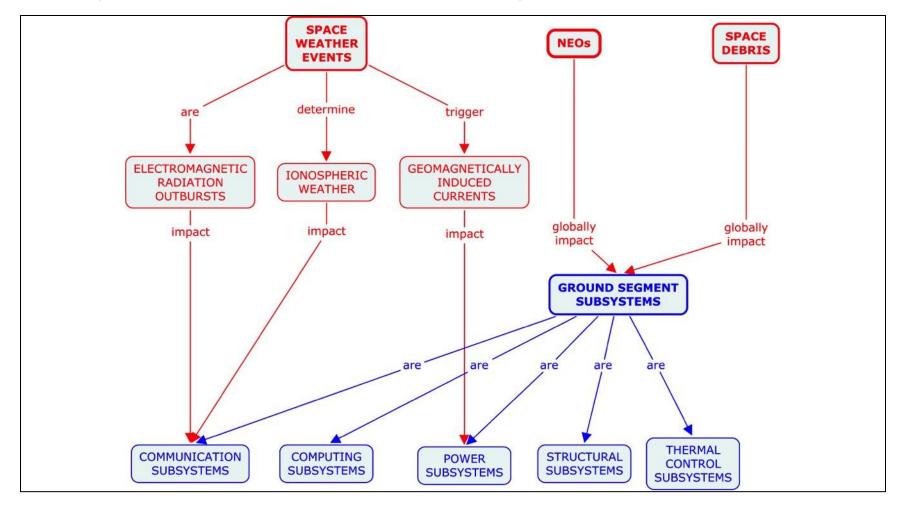
#### An Extreme Space Weather Event

- a. Can cause the unavailability of many services on which NATO operations rely on (e.g. COMs).
- b. Is a mission-critical factor, as it can completely jeopardise specific operations despite of the backup/mitigation techniques.
- c. Forecasts, nowcasts and prompt warnings are a must.

### Satellite Segment Sub-Systems Affected by SWx Events



### Ground-System Segment Sub-Systems Affected by SWx Events



### SWx Monitoring and Warning for NATO Operations

- No ISES-like dedicated NATO network<sup>1</sup>, as national facilities can be shared or not with Partners according to the principle of national sovereignty preservation.
- Monitoring and warnings are derived from:
  - a. Governmental/Institutional Public Services.
  - b. Non-Public Services (DoD-customised public services).
  - c. Classified Services (DoD-proprietary).

<sup>1</sup>To my knowledge...

## Characteristics of SWx Information for Successful Operations

- Target-dependent (operator, specialist, soldier)
- Prompt
- Essential
- Comprehensive
- Standard
- User Friendly
- On Global effects
- On Regional effects
- On Local effects
- With Alerts and Warnings w/nowcast and forecast

## THANK YOU FOR YOUR ATTENTION!